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(54) **RETROREFLECTING POLARIZER**
RETROREFLEKTIERENDER POLARISATOR
POLARISEUR A RETROREFLEXION

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- **PATENT ABSTRACTS OF JAPAN vol. 10, no. 298 (P-505) 9 October 1986; & JP-A-61 114 205**

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Description

Technical Field

This invention relates to polarizing thin film stacks coated onto substrates having structured surfaces.

Background

A MacNeille polarizer comprises alternating repeating layers of a pair of thin film materials deposited on a bulk substrate material. The pair of thin film materials comprises one low refractive index material and one high refractive index material. The indices, called a MacNeille pair, are chosen such that, for a given angle of incidence of a light beam, the reflection coefficient for p-polarized light (r_p) is essentially zero at each thin film interface. The angle at which r_p is zero is called the Brewster angle, and the formula relating the Brewster angle to the numerical values of the indices is called the MacNeille condition. The reflection coefficient for s-polarized light (r_s) is non-zero at each thin film interface. Therefore, as more thin film layers are added, the total reflectivity for s-polarized light increases while the reflectivity for p-polarized light remains essentially zero. Thus, an unpolarized beam of light, incident upon the thin film stack, has some or all of the s-polarized components reflected while essentially all of the p-polarized component is transmitted.

Such a thin film stack is deposited on two general types of substrates, which then classifies the type of polarizer produced as either immersed or non-immersed. For example, if the thin films are deposited on a flat face which forms the hypotenuse side of a right angle (Porro) prism, and bonded to the similar side of an identical prism, the polarizer is an immersed polarizer. If the thin films are bonded between two planar slabs of transparent media, the polarizer is a non-immersed polarizer. In general, a polarizer is non-immersed if the geometry of the bulk endapsulant does not affect the immersion constant $n_i*\sin(\theta_i)$ of the light beam in a thin film material m_i.

For either immersed or non-immersed polarizers, the p-polarization component of an incident light beam is transmitted, while the s-polarization component is reflected from the thin film stack at an angle equal to the angle of incidence. The total change in direction of the s-polarization component from the incident direction is 90° for cube polarizers and usually about 60° for slab polarizers. Thus, the s-polarization component is typically unavailable for further use, leading to a decrease in overall intensity of light available, unless additional optics are employed to redirect the s-polarization component. For example, U.S. Patent 4,913,529 (Goldenberg et al.) discloses a liquid crystal display (LCD) television projection system using two reflectors, a polarization rotator and a prism to recombine both components.

Such systems are undesirably large for use in many common visual display systems, such as overhead projectors, and especially in portable or laptop computer displays where a thin profile is desired.

DE-A-2 137 422 discloses a retroreflecting polarizer where one polarized component of light is retroreflected and the other polarized component is transmitted. A birefringent material is used for the polarizing prism. Additional prism elements are positioned next to the polarizing prism so as to cause the transmitted polarized component to leave the system of prism elements in the same direction as the light incident on the polarizing prism.

Disclosure of Invention

The invention is a retroreflecting polarizer, comprising:

(a) a first layer of a transparent flexible material having a smooth surface and an opposite structured surface, the structured surface consisting of a linear array of substantially right angled isosceles prisms arranged side by side and having sides which are perpendicular to each other and which make an angle of approximately 45° with respect to said smooth surface;

(b) a second layer of a transparent flexible material configured essentially like the first layer, the structured surfaces of the first and second layers having substantially the same dimensions so that they can mate with each other;

(c) on the structured surface of at least one of said layers, at least one optical stack of alternating thin layers of high and low refractive index materials; the first and second layers and said thin layers all optically cemented to form a single unit in which the structured surfaces face each other with the alternating thin layers positioned therebetween and in which the refractive index of the first and second layers and the refractive indices and optical thicknesses of the layers of the optical stack are such that selective reflection of polarized light is produced so that:

(d) a light beam of mixed polarization incident on the unit from one side is separated by the optical stack into an s-polarized component and a p-polarized component,

(e) the s-polarized component is reflected from where the beam is incident on the optical stack onto another portion of the optical stack and there reflected parallel to the beam incident on the optical stack but propagating in the opposite direction so that this component leaves the unit in the direction opposite that of the beam incident on the unit, and

(f) the p-polarized component is transmitted through the unit and leaves the unit parallel to the beam incident on the unit.

Brief Description of the Drawing

Figure 1 is a cross sectional view of a portion of one preferred embodiment of the invention.

Figure 2 is an enlarged sectional view of a portion of the embodiment of Figure 1.

Figure 3 is a schematic side view of an optical system employing the invention.

Figure 4 is a graph of the transmissivity and reflectivity of light incident upon one embodiment of the invention.

Detailed Description of the Invention

Figures 1 and 2 show an inventive retroreflecting polarizer 10, comprising two pieces of transparent substrate material 12 and 14, between which is is a composite optical stack 16.

The pieces 12,14 each have structured surfaces (which face each other), and non-structured surfaces. As shown, piece 12 is a top layer and piece 14 is a substrate, but the entire assembly may be inverted with no loss of functionality, essentially interchanging the roles of the two pieces.

In the embodiment shown, the composite optical stack 16 is deposited upon the structured surface of the upper piece 12, and the structured surface of the lower piece 14 is optically cemented (i.e., adhered by a very thin layer of transparent adhesive) to the composite optical stack 16 by an adhesive 24 to form a single unit. However, the composite optical stack could comprise two sub-stacks, one sub-stack deposited on the top layer and the other deposited on the substrate, with adhesive 24 between the two sub-stacks.

The composite optical stack comprises at least one set of pairs of alternating layers of materials having low and high indices of refraction compared to each other. The thicknesses of the layers are chosen such that the quarterwave criterion is met for the wavelength of the incident collimated light beam 18 by each of layers 20 and 22. The shape of the structured surfaces, the optical properties of the substrate material, and the properties of the composite optical stack, all combine to divide the incident light beam into two polarization components. One component, 18-s, is reflected twice in such a manner as to be retroreflected, i.e., directed back toward the source of light beam 18. The other component, 18-p, is transmitted parallel to incident beam 18.

(In Figure 2, the division of incident light 18 into components 18-s and 18-p is shown as occurring at the first interface between the substrate and the composite optical stack, but this is illustrative only. Actually, some division occurs at each interface between thin films, with the net result being as shown.)

In the embodiment shown, the composite optical stack comprises a repeating stack of a pair of materials. One of the materials is a relatively low refractive index (n_L) material 20, and the other is a relatively high index (n_H) material 22. The construction of such a stack 16 is abbreviated $(HL)^2$. In general, more layers are used, such as a $(HL)^5$ stack, and generally the average optical thickness of each material is a quarterwave thick, with reference to a chosen wavelength of interest (typically but not necessarily in the visible spectrum). However, to optimize performance, the individual thicknesses of all thin film layers are varied slightly from the average thickness, in accordance with known principles, using commercially available software to calculate the desired values.

Also, more than two pairs of materials or average thicknesses may be used, such as a $(H_1L_1)^5+(H_2L_2)^5$. This would be done to extend the useful optical bandwidth of the invention or the range of angles over which the invention reflects essentially all s-polarized light.

Each of substrate pieces 12 and 14 comprises a transparent, preferably integral (i.e., a single continuous piece as opposed to an assembly or a laminate) material having a structured surface which consists of a linear array of substantially right angled isosceles prisms arranged side by side. The perpendicular sides of each prism make an angle of approximately 45° with respect to the smooth surface opposite the structured surface (or, in the most general case of a flexible substrate, with respect to the tangent to the structured surface). Angles other than 45° are useful for other applications, but angles near 45° (e.g., 40° to 50°) are preferred in this invention. This places a constraint on the design of the optical stack: only two of the three indices of refraction (n_L and n_H for the optical stack, n_O for the substrate pieces) can be chosen independently. (An additional implication is that n_L must always be less than n_O if high transmission of p-polarized light is desired at all wavelengths.) These values are determined by the MacNeille condition relating the Brewster angles of each material interface to the numerical values of the indices of the materials forming the interface:

$$\tan(\theta_L) = (n_H/n_L)$$

or,

$$\tan(\theta_H) = (n_L/n_H)$$

along with Snell's law relating θ_O to θ_L and θ_H.

In theory, an infinite set of values of n_H and n_L exist for a given n_O, but in practice, the available choices of materials for the substrate pieces and thin films are limited, and design of the invention reduces to choosing which of the limited set of values of n_H and n_L around that value of n_O will produce the desired results. The greater the difference between n_L and n_H, the wider the optical bandwidth over which the invention will divide incident light into separate polarizations.

A suitable thickness of the substrate is 0.36 millimeters, measured from the smooth surface to the lowest point of the grooves. Suitable groove heights (measured perpendicularly) are 0.18 mm. For such a film, about 28 peaks per centimeter is preferred, but there is wide lat-

itude in the dimensions.

Preferred substrate materials are homogeneous, and isotropic. Suitable materials include commercially available acrylics and polycarbonates having nominal indices of refraction of 1.49 and 1.59, respectively. Other possible materials, selected to provide the required functionality, include polypropylenes, polyurethanes, polystyrenes, and polyvinylchlorides. Generally, polycarbonates are preferred for their relatively high indices of refraction, clarity, and physical properties.

Higher index materials include polysulphone (and variations such as polyethersulphone and polyarylsulphone), polyethylene teraphthalate (PET), and polyethylene napthalate (PEN). The sulphones require high processing temperatures, but in turn can withstand higher ambient temperatures in use. PET and PEN may crystallize or exhibit birefringence depending on the process parameters. All these materials have indices in the range of 1.63 to 1.65, and as such, allow the use of the film pair SiO_2/TiO_2 while retaining high transmission of p-polarized light.

A suitable material is taught in U.S. Patent 4,805,984 (Cobb, Jr.), but in this invention the total internal reflection property of that material is not relevant, because the optical properties of the material are significantly changed when it is employed in this invention.

Suitable materials for the thin films 20 and 22 include any materials which are transparent (exhibit low absorption) in the spectrum of interest. For broadband visible light, suitable thin film materials are silicon dioxide (SiO_2) (n=1.45) ; amorphous hydrogenated silicon nitride (a-SiN:H) (n=1.68-2.0); titanium dioxide (TiO_2) (n=2.2-2.5) ; magnesium fluoride (MgF_2) (n=1.38) ; cryolite (Na_3AlF_6) (n=1.35) ; zinc sulphide (ZnS) (n=2.1-2.4); zirconium oxide (ZrO_2) (n=2.05); hafnium oxide (n=2.0); and aluminum nitride (n=2.2). Silicon nitride (Si_3N_4) is suitable, but has not been formed successfully on the preferred polycarbonate substrate.

Several thin film deposition techniques can be used to deposit the composite optical stack on the substrate. Thermal and electron beam evaporation, and ion beam sputtering are the methods of choice for precision optical coatings, the latter method producing superior films in terms of adhesion to the substrate, hardness, and environmental stability. Magnetron sputtering is also used extensively for broadband coatings such as anti-reflective coatings on glass, and especially for large area applications such as architectural glass. However, on the whole, thermal and electron beam evaporation should provide good thin film qualities and sufficiently high deposition rates for acceptable manufacturing rates. More importantly, low index films such as magnesium fluoride and cryolite can be deposited by this method. Electron beam deposition is regularly used in the coatings industry for high index materials such as titanium dioxide, zirconium oxide, hafnium oxide, and aluminum nitride.

The process used in the reduction to practice of the invention was plasma assisted chemical vapor deposition (PACVD). Using this PACVD, the following procedures and resultant products are possible.

SiO_2 may be deposited by reacting silane (SiH_4) or almost any organosilane in the PAVCD process with oxygen or nitrous oxide at between 50 and 250 milliTorr, using low power RF plasmas of about 538.2-1076.4 watt/m^2 (50-100 watt/ft^2) of electrode area. Nitrous oxide is somewhat preferred because it generally results in less powder formations in the gas phase.

TiO_2 may be formed by reacting titanium tetrachloride ($TiCl_4$) with oxygen and nitrous oxide at the same power levels. By varying both the relative and absolute flow rates of the O_2 and N_2O for a given flow of $TiCl_4$ vapor, the index of refraction of the film is easily varied, from 2.0 to 2.4. Residual chlorine in the film can result in poor adhesion to polycarbonate. An oxygen flow of several times in excess of the reactant gas is preferred.

The visibly transparent a-SiN:H material has an index of refraction which varies mainly as a function of deposition temperature, with the higher indices requiring temperatures of 250 Celsius or more. The films may be deposited from mixtures of silane, ammonia, and nitrogen. Films formed at lower temperatures from conditions suitable for high index films (i.e., silane, starved nitrogen, no ammonia) produce undesirably high absorption of blue light. It is possible to form films having indices between 1.68 and 1.8 on polycarbonate below 100 C, with low optical absorption, although the lower index films are somewhat brittle.

The PACVD process was carried out using a deposition system according to the teachings of U.S. Patents 4,841,908 and 4,874,631 (Both Jacobson, et al.). Briefly, this multi-chamber deposition system employs a large volume vacuum chamber within which are plurality of deposition chambers for different composition layers, each chamber having separate seals to minimize back diffusion of any dopant gases from adjacent deposition chambers. A continuous roll of substrate proceeds from a supply roll through each of the deposition chambers and onto a finished take-up roll. The direction of web travel is reversed repeatedly to produce the multiple layers of repeating refractive index materials.

The index of refraction (n_A) of the adhesive 24 should match that of the upper and lower pieces 12 and 14 as closely as possible. When the index of the adhesive is less than that of the adjoining piece, the non-zero thickness of the adhesive leads to some refraction of light away from the original beam direction. Adhesives of n_A = 1.56 are available from the Norlund Company. Suitable adhesives are Norlund numbers 61 and 81 optical cements (n_A = 1.56). Another ultraviolet curable resin (n_A = 1.50) can be made from Union Carbide number ERL 4221 epoxy resin with 1% (by weight) Minnesota Mining and Manufacturing Company number 41-4201-91185 sulphonium salt initiator. The initiator is dissolved in methelene chloride which must be evaporated off before mixing with the epoxy. Other UV curable mixtures, not as preferred, may be made from urethane

acrylate base resins, diacrylate diluents, and suitable photoinitiators. UV curable adhesives may cause slight absorption, mainly in the blue end of the spectrum, in the completed polarizer of about 1-2%. Any thermosetting adhesive or epoxy will work also provided it has low optical absorption and high index.

Example

Alternating thin film layers of matched quarterwave optical thickness were coated on the structured side of a 14 mil thick polycarbonate version of the preferred substrate material described in U.S. Patent 4,805,984 (Cobb, Jr.) In Example 1, coating was done by the plasma assisted chemical vapor deposition (PACVD) process described above, using a 0.12 m (5 inch) wide and 0.2 m (8 inch) long gas "showerhead" type electrode. To form the retroreflective polarizer, an uncoated piece of the TIR material was adhered to the optical stack with an optical adhesive.

In Example 1, the polarizer had three optical stacks, each having twelve layers, either silicon dioxide (SiO_2) or titanium dioxide (TiO_2). The unusually high number of layers was required because the PACVD technique as described above did not produce a uniform film thickness near the prism peaks as opposed to the bottoms of the grooves. The first stack had a quarterwave thickness centered at 400 nm, the next centered at 550 nm, the third centered at 700nm. The polarizer performance is shown in Figure 4. Transmissivity of the s-polarization component, T(s), was at or near zero throughout nearly all the visible spectrum, while reflectivity of that component, R(s), approached the 95% level typical of the most efficient common reflectors. Transmissivity of the p-polarization component, T(p), was very acceptable, nearly 80% or more throughout the visible spectrum.

It is useful to provide a few details of the angular dependence of the retroreflecting polarizer. The first feature is the angular dependence of transmission for p-polarized light, through one prism facet. The angle theta is measured in air from the unit vector normal to the outside surface of the retroreflecting polarizer. The assumed film stack is a combination of three stacks designed to cover the visible spectrum at all angles of incidence. The transmission spectrum vs. angle is broader at longer wavelengths (±45° at 650 nm). This stack comprises twenty-eight layers: an eight layer stack centered at 600 nm and 45° (immersed), along with a double stack, of ten layers each, designed for 15°, with center wavelengths of 450 and 600 nm.

The computer calculated angular dependence of transmission, for a wavelength of 450 nm, shows an assymmetry of p-polarized transmission for positive and negative values of theta. This arises from the inclination of the prism facets at 45° from the substrate surface, whereas the angle theta is measured in air from the normal to the outside surface. Total transmission through the polarizer is the sum of two transmissions, at complimentary angles, through two opposing facets. When both terms are taken into account, the transmission curve is symmetrical. Tertiary and higher order reflections from light transmitted laterally at the second prism can be accounted for as well, but do not have a great impact on the shape of the curve.

Applications

The invention is suitable for applications requiring polarized light that would benefit from increasing the intensity of the polarized light available from an unpolarized source, and especially those requiring polarized light over relatively large areas and/or in relatively compact (especially thin) applications.

For example, the inventive retroreflecting polarizer can be combined in a very simple manner with a quarterwave retardation plate and a reflector to recombine the two components of an incident light beam into a single polarized component of light. Such an arrangement is shown in Figure 3. A combined reflector and source of incident light 118 is illustrated schematically as 130. Incident light 118, having mixed polarization, is not affected by quarterwave retardation plate 120, but is split into components 118-p and 118-s by retroreflecting polarizer 100. Component 118-p is transmitted directly to display device 110. Component 118-s is retroreflected back through a quarterwave retardation plate 120 as shown by 119, and reflected (and displaced transversely upward for clarity as component 121) back through the quarterwave retardation plate again as shown by 121. The two passes through the quarterwave retardation plate represent a total rotation of 90°, i.e., component 118-s now has the same polarization direction as component 118-p, and is also directed toward display device 110, thus nearly all of the intensity of incident unpolarized light 118 is available in polarized form at display device 110.

The great advantage of the invention in this system is that because all components may be relatively thin and large in area, and lie on essentially the same optic axis, the profile of the system can be greatly reduced. Where reduction in profile is not as much a concern, or where convenient for other reasons, the optic axis can be redirected without loss of generality.

Reflecting source 130 may be the light source of a backlit computer display, or an overhead projector such as models widely available from the Minnesota Mining and Manufacturing Company. Display device 110 may be a group of one or more birefringent LCD panels, employed in monochrome or color applications, such as those disclosed in U.S. Patents 4,917,465 (Conner et al.) and 4,966,441 (Conner).

For this application, assuming a polycarbonate substrate of index $n_O = 1.586$, the ideal thin film indices are $n_H = 2.0$ and $n_L = 1.35$. With this pair of indices, the theoretical minimum composite optical stack for a photoptic (i.e., covering the entire visible spectrum) retroreflecting

polarizer is two sets of eight layers, i.e., $(HL)^4+(H'L')^4$. One set has a bandwidth centered on 425 nm and the other has a bandwidth centered on 650 nm. Although cryolite has the most desired low index (n_L = 1.35), it is soft and slightly hygroscopic, so magnesium fluoride (n_L = 1.38) is preferred. Zirconium oxide (n_H = 2.05) is one preferred high index material, although several other materials are suitable.

Claims

1. A retroreflecting polarizer (10; 100) comprising:

    a) a first layer (12) of a transparent flexible material having a smooth surface and an opposite structured surface, the structured surface consisting of a linear array of substantially right angled isosceles prisms arranged side by side and having sides which are perpendicular to each other and which make an angle of approximately 45° with respect to said smooth surface;
    b) a second layer (14) of a transparent flexible material configured essentially like the first layer, the structured surfaces of the first and second layers having substantially the same dimensions so that they can mate with each other;
    c) on the structured surface of at least one of said layers, at least one optical stack (16) of alternating thin layers (20, 22) of high and low refractive index materials;

    the first and second layers (12, 14) and said thin layers (20, 22) all optically cemented to form a single unit (10; 100) in which the structured surfaces face each other with the alternating thin layers (20, 22) positioned therebetween and in which the refractive index of the first and second layers (12, 14) and the refractive indices and optical thicknesses of the layers (20, 22) of the optical stack (16) are such that selective reflection of polarized light is produced so that:

    d) a light beam of mixed polarization (18; 118) incident on the unit from one side is separated by the optical stack (16) into an s-polarized component (18-s; 118-s) and a p-polarized component (18-p; 118-p),
    e) the s-polarized component is reflected from where the beam is incident on the optical stack onto another portion of the optical stack and there reflected parallel to the beam incident on the optical stack but propagating in the opposite direction so that this component leaves the unit in the direction opposite that of the beam incident on the unit, and
    f) the p-polarized component is transmitted through the unit and leaves the unit parallel to the beam incident on the unit.

2. The polarizer of claim 1 wherein the angle that said sides of said prisms make with respect to said smooth surface is 40°-50°.

3. The polarizer of claims 1 or 2, wherein the optical stack comprises at least two sub-stacks: a first substack having a bandwidth centered on a first wavelength within the visible spectrum and a second sub-stack having a bandwidth centered on a second wavelength, different from the first wavelength, within the visible spectrum.

4. The polarizer of claim 3, wherein the optical stack further comprises a third sub-stack having a bandwidth centered on a third wavelength within the visible spectrum.

5. An optical system comprising, along a common optical axis:

    a) the retroreflecting polarizer (100) of claim 1;
    b) a display device (110) employing polarized light located adjacent the retroreflecting polarizer (100);
    c) a source of incident light of mixed polarization (118) located adjacent the retroreflecting polarizer (100) and opposite the display device (110);
    d) a reflector (130) located adjacent the light source and opposite the retroreflecting polarizer (100); and
    e) a quarterwave retardation plate (120) located between the reflector (130) and the retroreflecting polarizer (100), in which the p-polarized component (118-p) is transmitted to the display device (110), and the s-polarized component (118-s) is retroreflected from the retroreflecting polarizer (100), passes through the quarterwave retardation plate (120) to the reflector (130) where it is reflected back through the quarterwave retardation plate (120) a second time thereby becoming a second p-polarized component (121) before proceeding to the display device (110).

Patentansprüche

1. Retroreflektierender Polarisator (10;100), umfassend:

    (a) eine erste Schicht (12) eines transparenten flexiblen Materials mit einer glatten Oberfläche und einer gegenüberliegenden strukturierten

Oberfläche, wobei die strukturierte Oberfläche aus einer linearen Gruppen von im wesentlichen rechtwinkligen, nebeneinander angeordneten, gleichschenkligen Prismen ist und über Seiten verfügt, die zueinander senkrecht sind und einen Winkel von näherungsweise 45° in bezug auf die glatte Oberfläche bilden;

(b) eine zweite Schicht (14) eines transparenten flexiblen Materials mit im wesentlichen gleicher Konfiguration wie die erste Schicht, wobei die strukturierten Oberflächen der ersten und der zweiten Schichten im wesentlichen die gleichen Abmessungen haben, so daß sie aneinandergepaßt werden können;

(c) auf der strukturierten Oberfläche mindestens einer der Schichten mindestens einen optischen Satz (16) von alternierenden dünnen Schichten (20, 22) aus Materialien mit hoher und niedriger Brechzahl;

wobei die ersten und zweiten Schichten (12, 14) und die dünnen Schichten (20, 22) alle unter Bildung einer singulären Einheit (10;100) optisch verkittet sind, in der die strukturierten Oberflächen mit den dazwischen angeordneten alternierenden dünnen Schichten (20, 22) einander zugewandt sind, und in der die Brechzahl der ersten und zweiten Schichten (12, 14) und die Brechzahlen und optischen Dicken der Schichten (20, 22) des optischen Satzes so beschaffen sind, daß eine selektive Reflexion von polarisiertem Licht derart erzeugt wird, daß:

(d) ein Lichtstrahl mit gemischter Polarisation (18; 118), der auf die Einheit von der einen Seite einfällt, durch den optischen Satz (16) in eine s-polarisierte Komponente (18-s;118-s) und eine p-polarisierte Komponente (18-p;118-p) aufgetrennt wird;

(e) die s-polarisierte Komponente von dort, wo der Strahl auf den optischen Satz eingefallen ist, auf einen anderen Abschnitt des optischen Satz reflektiert wird und dort parallel zu dem auf den optischen Satz einfallenden Strahl reflektiert wird, sich jedoch in die entgegengesetzte Richtung so ausbreitet, daß diese Komponente die Einheit in der entgegengesetzten Richtung zu dem auf die Einheit einfallen Strahl verläßt; sowie

(f) die p-polarisierte Komponente durch die Einheit durchgelassen wird und die Einheit parallel zu dem auf die Einheit einfallen Strahl verläßt.

2. Polarisator nach Anspruch 1, bei welchem der Winkel, den die Seiten der Prismen in bezug auf die glatte Oberfläche bilden, 40°... 50° beträgt.

3. Polarisator nach Anspruch 1 oder 2, bei welchem der optische Satz mindestens zwei Untersätze umfaßt: einen ersten Untersatz mit einer Bandbreite mit einer ersten Wellenlänge innerhalb des sichtbaren Spektrums als Zentrum; und einem zweiten Untersatz mit einer Bandbreite mit einer zweiten Wellenlänge innerhalb des sichtbaren Spektrums im Zentrum, die von der ersten Wellenlänge verschieden ist.

4. Polarisator nach Anspruch 3, bei welchem der optische Satz ferner einen dritten Untersatz mit einer Bandbreite mit einer dritten Wellenlänge innerhalb des sichtbaren Spektrums im Zentrum umfaßt.

5. Optisches System, umfassend entlang einer gemeinsamen optischen Achse:

(a) den retroreflektierenden Polarisator (100) nach Anspruch 1;

(b) ein Display (110) unter Einsatz von polarisiertem Licht, angeordnet neben dem retroreflektierenden Polarisator (100);

(c) eine Quelle für einfallendes Licht gemischter Polarisation (118), angeordnet neben dem retroreflektierenden Polarisator (100) und gegenüber dem Display (110);

(d) einen Reflektor (180), angeordnet neben der Lichtquelle und gegenüber dem retroreflektierenden Polarisator (100); sowie

(e) ein Viertelwellenplättchen (120), angeordnet zwischen dem Reflektor (130) und dem retroreflektierenden Polarisator (100), worin die p-polarisierte Komponente (118-p) durch das Display (110) durchgelassen wird und die s-polarisierte Komponenten (118-s) von dem retroreflektierenden Polarisator (100) retroreflektiert wird, durch das Viertelwellenplättchen (120) zum Reflektor (130) hindurchgeht, wo es durch das Viertelwellenplättchen (120) hindurch ein zweites Mal reflektiert wird und dadurch zu einer zweiten p-polarisierten Komponente (121) wird, bevor es zum Display (110) weitergeht.

Revendications

1. Polariseur à rétroréflexion (10; 100), comprenant :

a) une première couche (12) d'un matériau flexible transparent ayant une surface lisse et une surface structurée opposée, la surface structurée consistant en un arrangement linéaire de prismes isocèles à angle sensiblement droit, disposés côte à côte et ayant des faces qui sont perpendiculaires les unes aux autres et qui font un angle de 45° approximativement par rapport à ladite surface lisse;

b) une seconde couche (14) d'un matériau flexible transparent configurée essentiellement comme la première couche, les surfaces structurées des première et seconde couches ayant substantiellement les mêmes dimensions, de façon qu'elles puissent correspondre l'une à l'autre;

c) sur la surface structurée d'au moins une desdites couches, au moins un empilement optique (16) de couches minces alternées (20, 22) de matériaux d'indices de réfraction faible et élevé;

les première et seconde couches (12, 14) et lesdites couches minces (20, 22) toutes cimentées optiquement pour former une unité unique (10; 100) dans laquelle les surfaces structurées se font face entre elles, avec les couches minces alternées (20, 22) positionnées entre, et dans laquelle l'indice de réfraction des première et seconde couches (12, 14), et les indices de réfraction et les épaisseurs optiques des couches (20, 22) de l'empilement optique (16) sont tels qu'une réflexion sélective de la lumière polarisée est fournie de sorte que :

d) un faisceau lumineux de polarisation mixte (18) incident à l'unité par un côté est séparé par l'empilement optique (16) en une composante polarisée s (18-s; 118-s) et une composante polarisée p (18-p; 118-p),

e) la composante polarisée p est réfléchie à partir du point où le faisceau est incident sur l'empilage optique, sur une autre partie de l'empilage optique et là, réfléchie parallèlement au faisceau incident sur l'empilage optique, mais en se propageant dans la direction opposée, de façon que cette composante quitte l'unité dans la direction opposée à celle du faisceau incident à l'unité, et

f) la composante polarisée p est transmise à travers l'unité et quitte l'unité parallèlement au rayon incident à l'unité.

2. Polariseur selon la revendication 1, dans lequel l'angle que font lesdites faces desdits prismes par rapport à ladite surface lisse est de 40 à 50°.

3. Polariseur selon les revendications 1 ou 2, dans lequel l'empilement optique comprend au moins deux sous-empilements : un premier sous-empilement ayant une largeur de bande centrée sur une première longueur d'onde à l'intérieur du spectre visible et un second sous-empilement ayant une largeur de bande centrée sur une seconde longueur d'onde, différente de la première longueur d'onde, appartenant au spectre visible.

4. Polariseur selon la revendication 3, dans lequel l'empilement optique comprend en outre un troisième sous-empilement ayant une largeur de bande centrée sur une troisième longueur d'onde à l'intérieur du spectre visible.

5. Système optique comprenant, le long d'un axe optique commun :

a) le polariseur à rétroréflexion (100) de la revendication 1;

b) un dispositif d'affichage (110) employant de la lumière polarisée, placé à proximité du polariseur à rétroréflexion (100);

c) une source de lumière incidente de polarisation mixte (118), placée à proximité du polariseur à rétroréflexion (100) et opposée au dispositif d'affichage (110);

d) un réflecteur (130) situé à proximité de la source lumineuse et opposé au polariseur à rétroréflexion (100); et

e) une plaque retard quart d'onde (120) placée entre le réflecteur (130) et le polariseur à rétroréflexion (100), dans laquelle la composante polarisée p (118-p) est transmise au dispositif d'affichage (110) et la composante polarisée s (118-s) est rétroréfléchie par le polariseur à rétroréflexion (100), traverse la plaque retard quart d'onde (120) vers le réflecteur (130), où elle est réfléchie vers l'arrière à travers la plaque retard quart d'onde (120) une seconde fois, devenant ainsi une seconde composante polarisée p (121) avant de parvenir au dispositif d'affichage (110).

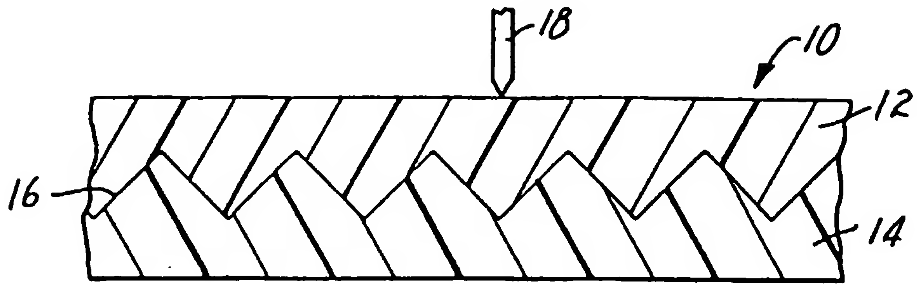

FIG. 1

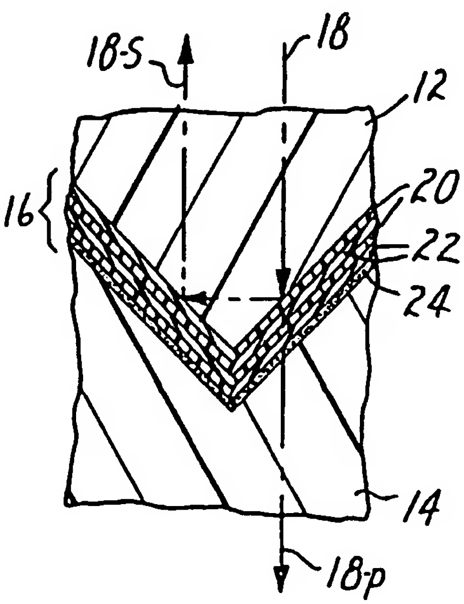

FIG. 2

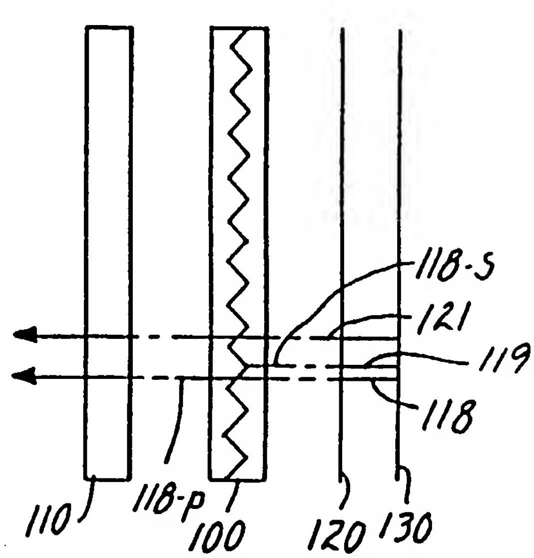

FIG. 3

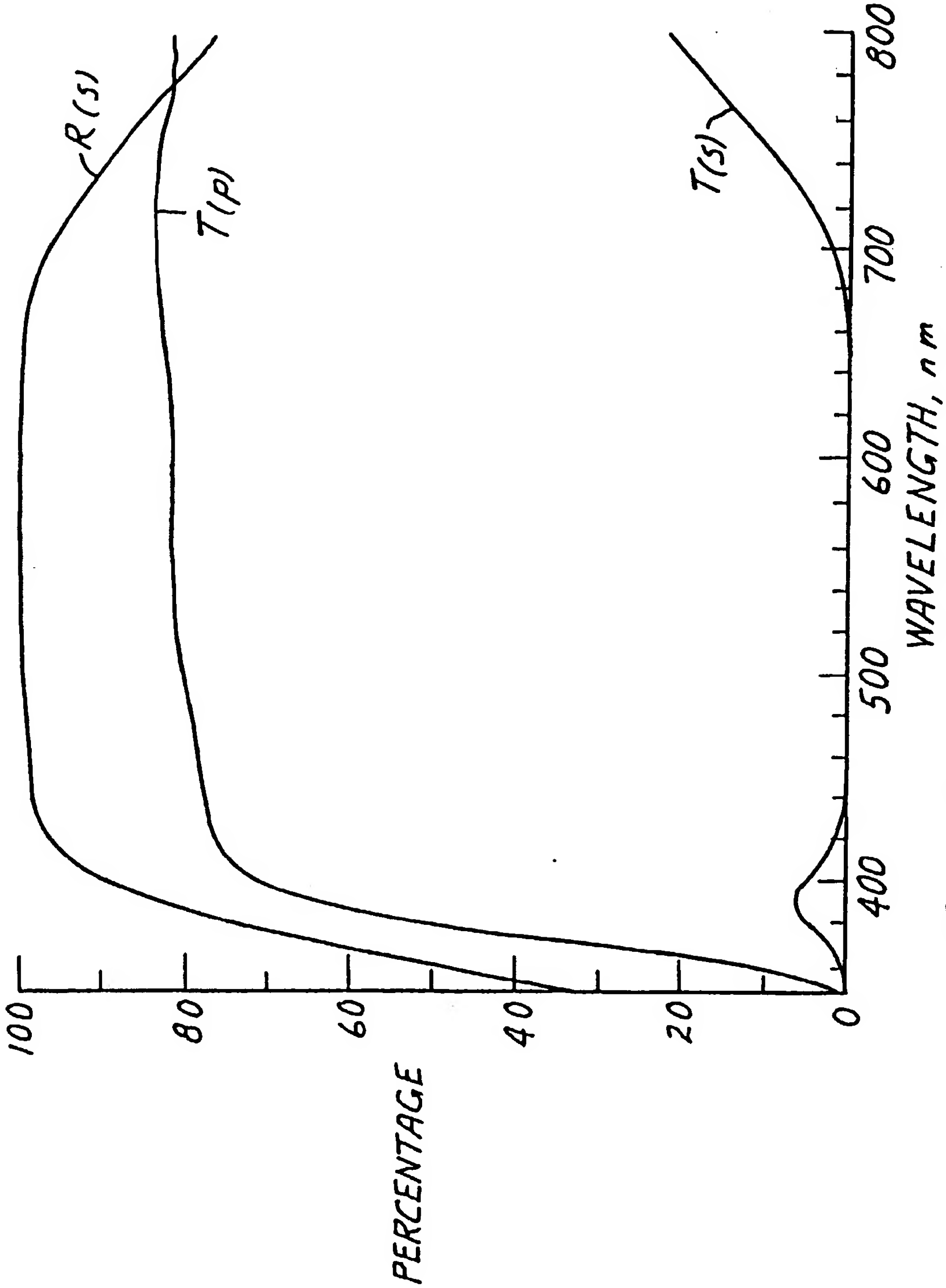
100
80
60
40
20
0
PERCENTAGE
400
500
600
700
800
WAVELENGTH, nm
R(s)
T(p)
T(s)

FIG. 4